TITLE OF THE INVENTION

OPTICAL TRANSMISSION SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

[0001]   The present invention relates to an optical transmission system for transmitting signal light (multiplexed signal light), where a plurality of signal channels included in a signal wavelength band are multiplexed, via an optical fiber transmission line.

Related Background Art

[0002]   A Wavelength Division Multiplexing (WDM) optical transmission system transmits multiplexed signal light including a plurality of signal channels via an optical fiber transmission line so as to enable the high-speed transmission/reception of large capacity information.   The optical transmission system can suppress waveform deterioration of signal light by decreasing the absolute value of the accumulated chromatic dispersion of an entire signal light propagation path. By this, the optical transmission system can increase the bit rate and allow larger capacity.

[0003]   For example, the optical transmission system disclosed in Japanese Patent Laid-Open No. 11-204866 has a configuration for demultiplexing a plurality of signal channels included in the multiplexed signal light into a plurality of bands, and performing dispersion

compensation for each band, by this, the absolute value of the accumulated chromatic dispersion is decreased for each band.

[0004]   In Document 1, "D. A. Atlas, 'Chromatic dispersion limitations due to semiconductor laser chirping in conventional and dispersion-shifted single-mode fiber systems', Optics Letters, Vol. 13, No. 11, pp. 1035 – 1037 (1988)", the relationship between the accumulated chromatic dispersion and the transmission characteristics, in a system where a direct modulation semiconductor laser light source is applied for the signal light source, is shown. In Document 1, the values of dispersion resistance, to acquire good signal light transmission quality, are stated, where the dispersion resistance is 1200 ps/nm when the bit rate is 2.5 Gb/s, and the dispersion resistance is 80 ps/nm when the bit rate is 10 Gb/s.

[0005]   The optical transmission system stated in Document 2, "M. Kakui, et al, '2.4 Gbit/s repeaterless transmission over 306 km non-dispersion-shifted fiber using directly modulated DFB-LD and dispersion-compensating fiber', Electronics Letters, Vol. 31, No. 1, pp. 51 – 52, (1995)" intends to make the absolute value of accumulated chromatic dispersion to roughly zero, where the direct modulation semiconductor laser light source is used as the signal light source and

dispersion-compensating optical fiber is used as the dispersion compensator.

[0006]   Also in the optical transmission system stated in Document 3, "M. Tanaka, et al, 'Water-peak-suppressed non-zero dispersion shifted fiber for full spectrum coarse WDM transmission in metro networks', OFC 2002, WA2", an optical fiber having a loss peak due to an OH-radical near the wavelength of 1.38 μm is decreased, is applied. Document 3 shows the case where a direct modulation semiconductor laser light source is used for the signal light source, where the accumulated chromatic dispersion is about 1000 ps/nm and the transmission penalty is 1 dB when the bit rate is 2.5 Gb/s.

SUMMARY OF THE INVENTION

[0007]   After studying conventional optical transmission systems, the present inventor discovered the following problem. An optical transmission system which performs CWDM (Coarse WDM) optical transmission, in which the signal light channel spacing (signal wavelength spacing) is relatively wide (see Japanese Patent Laid-Open No. 2000-156702, for example), is generally applied to a route where communication demand is relatively small, and normally a semiconductor laser light source, which is used as the signal light source, is directly modulated, and dispersion compensation is not performed because of the demand to decrease system cost.

[0008]   On the other hand, optical fibers used as the optical fiber transmission line generally have positive chromatic dispersion in the signal wavelength, so when dispersion is compensated, dispersion compensating optical fiber, having negative chromatic dispersion in the signal wavelength, is inserted in the optical fiber transmission line. However, the dispersion compensator represented by the dispersion compensating optical fiber generally has the tendency for the insertion loss to increase as the absolute value of the dispersion compensating amount increases. Therefore, when dispersion is compensated more than necessary, the transmission loss of the entire system increases remarkably.

[0009]   With the foregoing in view, it is an object of the present invention to provide an optical transmission system which allows high quality transmission of signal light where a plurality of signal channels in the signal wavelength band are multiplexed, and has a structure which is particularly suitble for CWDM optical transmission.

[0010]   The optical transmission system according to the present invention comprises, an optical transmitter including a direct modulation light source, an optical receiver, at least one optical fiber transmission line disposed between the optical transmitter and the optical receiver, and at least one dispersion compensator. A

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plurality of signal channels included in the signal
wavelength band are multiplexed as signal light. The
optical receiver receives the signal light outputted from
the optical transmitter. The optical fiber transmission
line is a transmission medium through which the signal
light (multiplexed signal light), where the plurality of
signal channels are multiplexed, propagates. The
dispersion compensator disperse-compensates for the
signal channel group in the second wavelength band, other
than the first wavelength band including the
zero-dispersion wavelength of the optical fiber
transmission line. Of cause, the optical transmitter may
output some signal channels in the signal wavelength band.

[0011]   In this optical transmission system, a
plurality of signal channels are multiplexed by a
multiplexer first, then the multiplexed signal light
propagates through the optical fiber transmission line.
Then the signal channels included in the multiplexed signal
light are demultiplexed by the demultiplexer, and each
one of the signal channels are received by the optical
receiver, respectively. Therefore, in the configuration
where the dispersion compensator is disposed on an optical
path between the signal transmitting end of the optical
transmitter and the signal entering end of the optical
fiber, the multiplexer for multiplexing the signal channel
group in the second wavelength band among the plurality

of signal channels is disposed in the previous stage of
the dispersion compensator. In the case of the
configuration where the dispersion compensator is
disposed on one of an optical paths between the signal
outputting end of the optical fiber transmission line and
the signal receiving end of the optical receiver, the
demultiplexer, for demultiplexing the plurality of signal
channels into the signal channel group in the first
wavelength band and the signal channel group in the second
wavelength band, is disposed in the previous stage of the
dispersion compensator.

[0012]   Particularly, with the optical transmission
system according to the present invention, when the bit
rate is B (Gb/s) at the specific wavelength in the second
wavelength band where the total chromatic dispersion in
the optical fiber transmission line and the dispersion
compensator becomes the highest, the chromatic dispersion
value at this specific wavelength is grater than 0 (ps/nm)
but $7500/B^2$ (ps/nm) or less. Also, in this entire system
the loss of each signal channel in the second wavelength
band is smaller than the highest loss among of the losses
in the signal channels in the first wavelength band. Or
the lowest received power among the received powers for
the signal channels in the second wavelength band is higher
than the lowest optical power among the optical powers
in the optical fiber transmission line of the signal

channels in the first wavelength band.

[0013]   In accordance with the optical transmission system having the above mentioned structure, the chromatic dispersion in the signal channel group of the second wavelength band other than the first wavelength band, among the plurality of signal channels from the optical transmitter, is dispersion-compensated by the dispersion compensator which is disposed in a previous stage, in mid-stage, or in the subsequent stage of the optical fiber transmission line.   This is because the first wavelength band is a wavelength band including the zero-dispersion wavelength of the optical fiber transmission line, and the second wavelength band is the other wavelength band. In other words, the second wavelength band is a wavelength band where the absolute value of chromatic dispersion is larger than the first wavelength band near the zero-dispersion wavelength, so the chromatic dispersion in the signal channel group of the second wavelength band is selectively dispersion-compensated. And by setting the chromatic dispersion characteristic and the loss characteristic of the entire system including the optical fiber transmission line and dispersion compensator of this system as mentioned above, the optical transmission system according to the present invention allows high quality transmission of signal light where a plurality of signal channels included in the signal wavelength band are

multiplexed, particularly CWDM optical transmission. Also, the dispersion compensator can be disposed only for the signal channels in the second wavelength band, and system cost decreases. Also, the signal channel spacing is wide in the CWDM optical transmission, so an inexpensive optical filter can be used as the demultiplexer.

[0014]   In the optical transmission system according to the present invention, it is preferable that the total chromatic dispersion in the optical fiber transmission line and the dispersion compensator is grater than 0 (ps/nm) but $7500/B^2$ (ps/nm) or less in all the signal channels in the second wavelength band. In this case, the amount of dispersion compensation in the second wavelength band can be decreased, and the increase of loss in the second wavelength band can be effectively suppressed. Therefore, higher quality signal light transmission becomes possible.

[0015]   Also, in the optical transmission system according to the present invention, it is preferable that the bit rate of at least one signal channel among the signal channels included in the second wavelength band is higher than any bit rate of all the signal channels in the first wavelength band. In this case, the transmission speed can be upgraded intentionally from the dispersion compensated side, therefore a system improvement with a simple configuration at low cost can be expected.

[0016]   In the optical transmission system according to the present invention, it is preferable that the dispersion compensator includes a dispersion compensating optical fiber. In this case, a decrease in loss can be expected when the amount of dispersion compensation is low, and an increase in loss in the second wavelength band can be suppressed more conspicuously.

[0017]   Also, in the optical transmission system according to the present invention, the optical fiber transmission line may include a single-mode optical fiber having a zero-dispersion wavelength near the wavelength of 1.3 µm. In this case, an optical fiber transmission line which includes a single-mode optical fiber, which has already been laid, can be used, so system cost decreases.

[0018]   In the optical transmission according to the present invention, it is preferable that the optical fiber transmission line, at the wavelength of 1.38 µm, has a transmission loss smaller than a transmission loss at the wavelength of 1.31 µm. In this case, the signal channel near the wavelength of 1.38 µm can be used, which makes larger capacity possible.

[0019]   In the optical transmission system according to the present invention, it is preferable that the optical fiber transmission line has a zero-dispersion wavelength which exists in a wavelength range of 1.35 µm to 1.5 µm.

In this case, the chromatic dispersion of the optical fiber transmission line at the shorter wavelength side of the signal wavelength band is at a negative value (or a slightly positive value), so the transmission characteristics of all the signal channels included in the signal wavelength band can be improved.

[0020]   It is also preferable that the optical transmission system according to the present invention further comprises pumping light supply means for supplying Raman amplification pumping light into this optical fiber transmission line, so as to Raman-amplify the signal light propagating through the optical fiber transmission line. In this case, the signal light is Raman-amplified in the optical fiber transmission line to which the Raman amplification pumping light is supplied, so an effective transmission loss can be decreased, and a loss increase due to the insertion of the dispersion compensator can be compensated.

[0021]   In the optical transmission system according to the present invention, the pumping light supply means may supply the Raman amplification pumping light, where a plurality of pumping channels included in a wavelength range of $1.2 \, \mu m$ to $1.3 \, \mu m$ are multiplexed, into the optical fiber transmission line. In this case, the signal channels near the wavelength of $1.31 \, \mu m$, where transmission loss is particularly high, is Raman-amplified, and an effective

transmission loss near this wavelength can be decreased.

[0022]   The optical transmission system according to the present invention may further comprise pumping light supply means for supplying Raman amplification pumping light, which Raman-amplifies the signal light propagating through the dispersion compensating optical fiber as a dispersion compensator, to the dispersion compensating optical fiber. In this case, an effective transmission loss of the dispersion compensating optical fiber can be decreased, and as a result, the loss budget can be increased and the reliability of the system can be improved.

[0023]   The present invention will be more fully understood   from   the   detailed   description   given hereinbelow and the accompanying drawings, which are given by way of illustration only and are not to be considered as limiting the present invention.

[0024]   Further scope of applicability of the present invention   will   become   apparent   from   the   detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will be apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025]   Fig. 1 is a diagram depicting the configuration of the first embodiment of the optical transmission system according to the present invention;

[0026]   Fig. 2 is a diagram depicting the configuration of the first application example of the optical transmission system according to the first embodiment shown in Fig. 1;

[0027]   Fig. 3 is a diagram depicting the configuration of the second application example of the optical transmission system according to the first embodiment shown in Fig. 1;

[0028]   Figs. 4A and 4B are graphs depicting the chromatic dispersion characteristics and the loss characteristics of the optical transmission system according to the first embodiment shown in Fig. 1;

[0029]   Fig. 5 is a graph showing the loss characteristics of the optical transmission system according to the first embodiment shown in Fig. 1;

[0030]   Fig. 6 is a diagram plotting the received power (input power to the receiver) for each channel in the optical transmission system according to the first embodiment shown in Fig. 1;

[0031]   Fig. 7 is a diagram depicting the configuration of the second embodiment of the optical transmission system according to the present invention;

[0032]   Fig. 8 is a diagram depicting the configuration of the third embodiment of the optical transmission system according to the present invention;

[0033]   Figs. 9A and 9B are graphs depicting the chromatic dispersion characteristics and the loss characteristics of the optical transmission system according to the third embodiment shown in Fig. 8;

[0034]   Fig. 10 is a diagram plotting the received power (input power to the receiver) for each signal channel in the optical transmission system according to the third embodiment shown in Fig. 8; and

[0035]   Fig. 11 is a diagram depicting the configuration of the fourth embodiment of the optical transmission system according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0036]   Embodiments of the optical transmission system according to the present invention will now be described in detail with reference to Figs. 1 to 3, 4A, 4B, 5 to 8, 9A, 9B, 10 and 11. In the descriptions of the drawings, identical composing elements are denoted with identical reference numerals, for which redundant descriptions are omitted.

(First Embodiment)

[0037]   At first, the first embodiment of the optical transmission system according to the present invention will be described. Fig. 1 is a diagram depicting the

configuration of the first embodiment of the optical transmission system according to the present invention. The optical transmission system 1 shown in Fig. 1 comprises N number of (N is an integer 2 or more) direct modulation light sources 11_1 to 11_N (included in the optical transmitter), multiplexer 12, N number of receivers 21_1 to 21_N (included in the optical receiver), demultiplexer 22, dispersion compensator 23, demultiplexer 24_1, demultiplexer 24_2 and optical fiber transmission line 30.

[0038] Each direct modulation light source 11_n (n is an arbitrary integer 1 or more N or less) includes a semiconductor laser light source which outputs light with wavelength λ_n (signal channel). The multiplexer 12 multiplexes signal channels with wavelength λ_n which are outputted from each direct modulation light source 11_n, and sends the multiplexed signal light (including the signal channels with wavelengths of λ_1 to λ_N) to the optical fiber transmission line 30. The signal channel wavelengths of λ_1 to λ_N are included in the signal wavelength band from about 1.3 μm to about 1.61 μm, and the channel spacing is relatively wide. In other words, this optical transmission system 1 is a system to perform CWDM optical transmission.

[0039] The optical fiber transmission line 30 transmits the multiplexed signal light, which is outputted from the multiplexer 12, into the demultiplexer 22. The

optical fiber transmission line 30 is preferably a standard single-mode optical fiber having a zero-dispersion wavelength near the wavelength of 1.3 μm, or a non-zero dispersion shifted optical fiber (NZDSF) having a zero-dispersion wavelength which exists in the wavelength range of 1.35 μm to 1.5 μm. It is preferable that the optical fiber transmission line 30, at the wavelength of 1.38 μm, has a transmission loss smaller than a transmission loss at the wavelength of 1.31 μm.

[0040]   The demultiplexer 22 is disposed in the subsequent stage of the optical fiber transmission line, and demultiplexes the signal channels with wavelengths of λ_1 to λ_N, which are included in the multiplexed signal light propagating through the optical fiber transmission line 30, into the signal channel group in the first wavelength Λ_1 and the signal channel group in the second wavelength band Λ_2. The first wavelength band Λ_1 is a wavelength band which includes the zero-dispersion wavelength of the optical fiber transmission line 30, and the second wavelength band Λ_2 is the other wavelength band. When the optical fiber transmission line 30 is a standard single-mode optical fiber, the second wavelength band Λ_2 locates at the longer wavelength side from the first wavelength band Λ_1.

[0041]   The dispersion compensator 23 dispersion-compensates for the chromatic dispersion of

the signal channel group with wavelengths of λ_{M+1} to λ_N (M is an integer 2 or more (N-1) or less) included in the second wavelength band Λ_2, which are demultiplexed by the demultiplexer 22. The dispersion compensator 23 has a chromatic dispersion with the opposite sign from the chromatic dispersion of the optical fiber transmission line 30 in the second wavelength band Λ_2. For the dispersion compensator 23, a dispersion compensating optical fiber, for example, is suitable, and in this case, loss is small, connection with other optical fibers is easy, and use in a wide band is possible. The dispersion compensator 23 may be a bulk type optical device, and in this case the dispersion compensator has periodicity, can be used in a wide band, where dispersion characteristics can be variable, and can be used even at high input power. And the dispersion compensator 23 may be a flat optical guide type optical device, and in this case downsizing is possible, the dispersion compensator 23 can be used in a wide band, and can be used at high input power.

[0042]   The demultiplexer 24_1 demultiplexes the signal channels with wavelengths of λ_1 to λ_M included in the first wavelength band Λ_1, which are demultiplexed by the demultiplexer 22, into each channel wavelength. The demultiplexer 24_2 inputs the signal channels with wavelengths of λ_{M+1} to λ_N included in the second wavelength band Λ_2 for which dispersion is compensated by the

dispersion compensator 23, and demultiplexes the signal channels into each channel wavelength. Each receiver 21_n receives the signal channel with wavelength λ_n, which is outputted from the demultiplexer 24_1 or the demultiplexer 24_2.

[0043] The optical transmission system 1 operates as follows. The signal channels with wavelength λ_n, which are outputted from the direct modulation light sources 11_n, are multiplexed by the multiplexer 12, and the multiplexed signal light, including the signal channels with wavelengths of λ_1 to λ_N, are sent to the optical fiber transmission line 30. The signal channels with wavelengths of λ_1 to λ_N included in the multiplexed signal light transmitted via the optical fiber transmission line 30 are demultiplexed into the signal channel group in the first wavelength band Λ_1 and the signal channel group in the second wavelength band Λ_2 by the demultiplexer 22. The signal channel group with wavelengths of λ_1 to λ_M included in the first wavelength band Λ_1, where the absolute value of the chromatic dispersion is small, which are demultiplexed by the demultiplexer 22, are further demultiplexed into each channel wavelength by the demultiplexer 24_1, and are received by the receivers 21_1 to 21_M respectively. The signal channel group with wavelengths of λ_{M+1} to λ_N included in the second wavelength band Λ_2, where the absolute value of the chromatic

dispersion is large, which are demultiplexed by the demultiplexer 22, are dispersion-compensated by the dispersion compensator 23, then demultiplexed into each channel wavelength by the demultiplexer 24_2, and received by the corresponding receivers 21_{M+1} to 21_N respectively.

[0044] At this time, when the bit rate is B (Gb/s) at a specific wavelength in the second wavelength band Λ_2 where the total chromatic dispersion becomes highest in the optical fiber transmission line 30 and the dispersion compensator 23, the chromatic dispersion value of this specific wavelength is set to be grater than 0 (ps/nm) but $7500/B^2$ (ps/nm) or less.

[0045] Also in the entire system, the loss at each signal channel in the second wavelength band Λ_2 is set to be lower then the highest loss among the losses of the signal channels in the first wavelength band Λ_1. Or the lowest received power among the received powers of the receiver for the signal light in the second wavelength band Λ_2 is set to be higher than the lowest optical power among the optical powers of the signal channels in the first wavelength band Λ_1 of the optical fiber transmission line 30. The total chromatic dispersion in the optical fiber transmission line 30 and the dispersion compensator 23 is preferably grater than 0 (ps/nm) but $7500/B^2$ (ps/nm) or less in the signal channels in the second wavelength band Λ_2, respectively. "$7500/B^2$" indicates the dispersion

resistance of the system.

[0046]　　　By setting the chromatic dispersion characteristics and the loss characteristics as above, the optical transmission system 1 allows high quality transmission of signal light where a plurality of signal channels included in the signal wavelength band are multiplexed, and becomes a configuration particularly suitable for CWDM optical transmission. Also the dispersion compensator 23 is disposed selectively only for the signal channels in the second wavelength band Λ_2, so system cost decreases. Also the channel spacing in the signal light is wide in CWDM optical transmission, so an inexpensive optical filter can be used for the demultiplexer 22.

[0047]　　　In the above mentioned configuration, the dispersion compensator 23 is disposed at the signal emitting end side of the optical fiber transmission line 30, but the dispersion compensator 23 may be disposed at the signal entering end side of the optical fiber transmission line 30, as shown in Fig. 2. Fig. 2 is a diagram depicting the configuration of the first application example of the optical transmission system 1a according to the first embodiment shown in Fig. 1.

[0048]　　　In the optical transmission system 1b according to the first application example, the signal channels with wavelengths of λ_1 to λ_M included in the first

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wavelength band Λ_1, which are outputted from the direct modulation light sources 11_1 to 11_M, are multiplexed by the multiplexer 12_1. The signal channels with wavelengths of λ_{M+1} to λ_N included in the second wavelength band Λ_2, which are outputted from the direct modulation light sources 11_{M+1} to 11_N, are multiplexed by the multiplexer 12_2.

[0049]   The signal channel group included in the second wavelength band Λ_2 is dispersion-compensated by the dispersion compensator 23, then is multiplexed by the multiplexer 13 along with the signal channel group included in the first wavelength band Λ_1. The multiplexed signal light, including the signal channels with wavelengths of λ_1 to λ_N, which are multiplexed by this multiplexer 13, propagates through the optical fiber transmission line 30, which is constituted by a single-mode optical fiber with a length of 100 km, for example, and reaches the demultiplexer 24.

[0050]   The multiplexed signal light which reaches the demultiplexer 24 is demultiplexed into each signal channel by the demultiplexer 24, and each signal channel is received by the receivers 21_1 to 21_N respectively, which are disposed corresponding to each signal channel.

[0051]   The optical transmission system according to the first embodiment can also perform hybrid transmission for a plurality of signal channels with different

transmission speeds. Fig. 3 is a diagram depicting the configuration of the second application example of the optical transmission system according to the first embodiment shown in Fig. 1, and has basically a configuration similar to the optical transmission system 1b according to the first application example shown in Fig. 2.

[0052]   In the optical transmission system 1c according to the second application example, the transmission speed of the signal channels with wavelengths of λ_1 to λ_M, which are outputted from the direct modulation light sources 11_1 to 11_M, is 2.5 Gb/s, while the transmission speed of the signal channels with wavelengths of λ_{M+1} to λ_N, which are outputted from the direct modulation light sources 11_{M+1} to 11_N, is 10 Gb/s. In this optical transmission system 1c, a signal channel with a high bit rate (10 Gb/s) is dispersion-compensated by the dispersion compensator 23, which is a dispersion compensating optical fiber (DCF).

[0053]   For example, in the optical transmission system 1c, signal channels within the range of 1490 nm to 1550 nm from the direct modulation light sources 11_1 to 11_M are multiplexed by the multiplexer 12_1 as a signal channel group in the first wavelength band Λ_1, where the transmission speed is 2.5 Gb/s. As the signal channel group in the second wavelength band Λ_2, where the

transmission speed is 10 Gb/s, on the other hand, the signal channels with wavelengths 1570 nm and 1590 nm from the direct modulation light sources 11_{M+1} to 11_N are multiplexed by the multiplexer 12_2. The signal channel group in the second wavelength band Λ_2 is further dispersion-compensated by the DCF 23, and chromatic dispersion is decreased until residual dispersion becomes less than 10 ps/nm. Then the signal channel group in the second wavelength band Λ_2 is multiplexed by the multiplexer 13 along with the signal channel group in the first wavelength band Λ_1. The multiplexed signal light, including the signal channels within the wavelength range of 1490 nm to 1590 nm, which are outputted from the multiplexer 13, propagates through the optical fiber transmission line (e.g. a single-mode optical fiber with a length of 50 km), and reaches the demultiplexer 24. In this demultiplexer 24, the multiplexed signal light is demultiplexed into signal channels, which are received by the receivers 21_1 to 21_N corresponding to these signal channels, respectively.

[0054] When upgradeable signal channels are determined in advance and dispersion compensation is performed for the signal channels by the dispersion compensator, such as DCF, as shown in this optical transmission system 1C, then the transmission speed can be easily upgraded from 2.5 Gb/s to 10 Gb/s merely by

switching the optical transmitter and the optical receiver.

[0055]   Figs. 4A and 4B are graphs depicting the chromatic dispersion characteristics and the loss characteristics of the optical transmission system 1 according to the first embodiment. Fig. 4A shows the dependency of accumulated chromatic dispersion on wavelength from the transmitter to the receiver, and Fig. 4B shows the dependency of loss on wavelength from the transmitter to the receiver. The optical fiber transmission line 30 is assumed to be a standard single-mode optical fiber with a length of 80 km. The dispersion compensator 23 is a dispersion compensating optical fiber having a chromatic dispersion of -100 ps/nm/km, a dispersion slope of 0 $ps/nm^2/km$, and a transmission loss of 0.5 dB/km, as characteristics at wavelength 1.55 µm. The insertion loss of the multiplexer 12, demultiplexer 24_1 and demultiplexer 24_2 is 3 dB, respectively. The insertion loss of the demultiplexer 22 is 1 dB. The 16-channel signal light (channel spacing 20 nm) in the wavelength range of 1.31 µm to 1.61 µm are transmitted at a bit rate of 2.5 Gb/s. In this case, the dispersion resistance of the system is 1200 ps/nm.

[0056]   When the dispersion compensator 23 is not disposed, the accumulated chromatic dispersion exceeds the dispersion resistance depending on the wavelength

(broken line in Fig. 4A). However in the optical transmission system 1 according to the first embodiment, each signal channel included in the second wave band Λ_2 (wavelength range of 1.48 μm to 1.61 μm), where the absolute

5   value of chromatic dispersion in the optical fiber transmission line 30 is large, is dispersion-compensated by the dispersion compensator 23, so the accumulated chromatic dispersion of the entire system is the dispersion resistance or less (solid line in Fig. 4A). The length

10   of the dispersion compensating optical fiber, which is the dispersion compensator 23, is adjusted such that the accumulated chromatic dispersion becomes the dispersion resistance or less at maximum wavelength 1.61 μm.

[0057] The loss of the dispersion compensator 23 is

15   3 dB. The highest loss in the first wavelength band Λ_1 is 32 dB at wavelength 1.31 μm, and the loss in the entire second wavelength band Λ_2 is 29 dB to 30 dB (Fig. 4B). When the accumulated chromatic dispersion in the entire second wavelength band Λ_2 attempts to be negative, the

20   loss in the entire second wavelength band Λ_2 becomes higher than the loss at wavelength 1.31 μm.

[0058] Fig. 5 is a graph depicting other loss characteristics of the optical transmission system 1 according to the first embodiment. Fig. 5 shows the

25   dependency of loss on wavelength from the transmitter to the receiver. Here the optical fiber transmission line

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30 is assumed to be a non-zero dispersion shifted optical fiber (NZDSF) with a length of 70 km. This non-zero dispersion shifted optical fiber has a zero-dispersion wavelength of 1.48 μm and a transmission loss of 0.2 dB/km at a wavelength of 1.55 μm. The dispersion compensator 23 is a dispersion compensating optical fiber having a chromatic dispersion of −80 ps/nm/km, a dispersion slope of 0.1 ps/nm^2/km, and a transmission loss of 0.5 dB/km, as characteristics at wavelength 1.55 μm. The insertion loss of the multiplexer 12, demultiplexer 24_1 and demultiplexer 24_2 is 3 dB respectively. The insertion loss of the demultiplexer 22 is 1 dB. The 16-channel signal light (channel spacing 20 nm) in the wavelength range of 1.31 μm to 1.61 μm are transmitted at a bit rate 10 Gb/s. In this case, the dispersion resistance of the system is 75 ps/nm.

[0059]   In this case as well, when the dispersion compensator 23 is not disposed, the accumulated chromatic dispersion exceeds the dispersion resistance depending on the wavelength. However in the optical transmission system 1 according to the first embodiment, each signal channel included in the second wavelength band Λ_2 (wavelengths of 1.5 μm to 1.61 μm), where the absolute value of chromatic dispersion in the optical fiber transmission line 30 is large, is dispersion-compensated by the dispersion compensator 23, so the accumulated

chromatic dispersion of the entire system is less than the dispersion resistance. The length of the dispersion compensating optical fiber, which is the dispersion compensator 23, is adjusted such that the accumulated chromatic dispersion at maximum wavelength 1.61 μm becomes the dispersion resistance or less. The highest loss in the first wavelength band Λ_1 is 27 dB at wavelength 1.31 μm, and the loss in the entire second wavelength band Λ_2 is 26 dB or less. The transmission penalty is 1 dB or less at all the wavelengths.

[0060]   Fig. 6 is a diagram plotting the received power (input power to the receiver) for each signal channel in the optical transmission system according to the first embodiment shown in Fig. 1. The optical transmission line 30 is assumed to be a standard single-mode optical fiber with a length of 80 km. The dispersion compensator 23 is a dispersion compensating optical fiber having a chromatic dispersion of −100 ps/nm/km, a dispersion slope of 0 ps/nm^2/km and a transmission loss of 0.5 dB/km, as characteristics at wavelength 1.55 μm. The insertion loss of the multiplexer 12, demultiplexer 24_1 and demultiplexer 24_2 is 3 dB, respectively. The insertion loss of the demultiplexer 22 is 1 dB. The 16-channel signal light (channel spacing 20 nm) in the wavelength range of 1.31 μm to 1.61 μm are transmitted at a bit rate of 2.5 Gb/s.

[0061]   In this system configuration, it was confirmed

that the lowest received power in the receivers 21_1 to 21_N is -31 dB or more, and is BER is $<10^{-11}$ in all the signal channels.

(Second Embodiment)

[0062]   Now the second embodiment of the optical transmission system according to the present invention will be described. Fig. 7 is a diagram depicting the configuration of the optical transmission system according to the present invention. The optical transmission system 2 shown in Fig. 7 further comprises an optical coupler 41 and an pumping light source 42, in addition to the configuration of the optical transmission system 1 according to the first embodiment (Fig. 1). In the following description, the dispersion compensator 23 is disposed at the signal emitting end side of the optical fiber transmission line 30, as shown in Fig. 7, but in the second embodiment, the dispersion compensator 23 may be disposed at the signal entering end side of the optical fiber transmission line 30, as shown in Fig. 2, as an application example, or the dispersion compensator 23 may be disposed in the middle of the optical fiber transmission line 30. This second embodiment may have a configuration which allows hybrid transmission, where the transmission speed is different among the signal channels, as shown in Fig. 3, as another application example.

[0063]   The pumping light source 42 outputs the Raman

amplification pumping light, which Raman-amplifies the multiplexed signal light, in the optical fiber transmission line 30. The optical coupler 41 is disposed in the subsequent stage of the optical fiber transmission line 30 and in the previous stage of the demultiplexer 22, and supplies the pumping light, which is outputted from the pumping light source 42, to the optical fiber transmission line 30, and also outputs the multiplexed signal light propagating through the optical fiber transmission line 30 to the multiplexer 22. It is preferable that the Raman amplification pumping light includes a plurality of pumping channels in the wavelength range of 1.2 μm to 1.3 μm, and in this case, the multiplexed signal light in the wavelength range of 1.3 μm to 1.4 μm can be Raman-amplified. At this time, it is preferable that the optical fiber transmission line 30 has a transmission loss at wavelength 1.38 μm, which is smaller than the transmission loss at wavelength 1.31 μm.

[0064]   This optical transmission system 2 operates as follows. The Raman amplification pumping light, which is outputted from the pumping light source 42, is supplied to the optical fiber transmission line 30 via the optical coupler 41. The signal channels with wavelength λ_n, which are outputted from the direct modulation light sources 11_n, are multiplexed by the multiplexer 12, and the multiplexed signal light, which includes the signal light

with wavelengths of λ_1 to λ_N, is sent to the optical fiber transmission line 30. While being transmitted via the optical fiber transmission line 30, the multiplexed signal light is Raman-amplified. And the signal channels with wavelengths of λ_1 to λ_N, included in the multiplexed signal light, which reaches the demultiplexer 22 via the optical coupler 41, are demultiplexed into the signal channel group in the first wavelength band Λ_1 and the signal channel group in the second wavelength band Λ_2 by the demultiplexer 22. The signal channel group with wavelengths of λ_1 to λ_M included in the first wavelength band Λ_1, where the absolute value of chromatic dispersion is small, demultiplexed by the demultiplexer 22, is demultiplexed into each signal channel by the demultiplexer 24_1, and each signal channel is received by the corresponding receivers 21_1 to 21_M respectively. The signal channel group with wavelengths of λ_{M+1} to λ_N included in the second wavelength band Λ_2, where the absolute value of chromatic dispersion is large, demultiplexed by the demultiplexer 22, is demultiplexed into each signal channel after dispersion is compensated by the dispersion compensator 23, and each signal channel is received by the corresponding receivers 21_{M+1} to 21_N, respectively.

[0065]   At this time, when the bit rate is B (Gb/s) at a specific wavelength in the second wavelength band Λ_2 where the total chromatic dispersion becomes highest

in the optical fiber transmission line 30 and the dispersion compensator 23, the chromatic dispersion value of this specific wavelength is set to be grater than 0 (ps/nm) but $7500/B^2$ (ps/nm) or less.

[0066]   Also in the entire system, the loss at each signal channel in the second wavelength band Λ_2 is set to be lower than the highest loss among losses of the signal channels in the first wavelength band Λ_1. Or the lowest received power among the received powers of the receiver for each signal channel in the second wavelength band Λ_2 is set to be higher than the lowest optical power among the optical powers of the signal channels in the first wavelength band Λ_1 of the optical fiber transmission line 30. It is preferable that the total chromatic dispersion in the optical fiber transmission line 30 and the dispersion compensator 23 is set to be grater than 0 (ps/nm) but $7500/B^2$ (ps/nm) or less in each signal channel in the second wavelength band Λ_2 respectively.

[0067]   By setting the chromatic dispersion characteristics and the loss characteristics as above, the optical transmission system 2 allows high quality transmission of the multiplexed signal light including a plurality of signal channels in the signal wavelength band, and becomes a configuration particularly suitable for CWDM optical transmission. Also the dispersion compensator 23 is disposed selectively only for the signal

channels in the second wavelength band Λ_2, so system cost decreases. Also the signal channel spacing is wide in the CWDM optical transmission, so an inexpensive optical filter can be used for the demultiplexer 22. Also according to the second embodiment, higher quality signal light transmission is possible by Raman-amplifying the signal channel group in a wavelength band where loss of the optical fiber transmission line 30 is high.

[0068]   In particular, the optical fiber transmission line 30 is assumed to be a non-zero dispersion shifted optical fiber having a loss peak due to an OH-radical near the wavelength of 1.38 μm is decreased. The 16-channel signal light (channel spacing 20 nm) in wavelength range of 1.31 μm to 1.61 μm are transmitted at a bit rate 2.5 Gb/s. In this case, the dispersion resistance of the system is 1200 ps/nm. The wavelength of each pumping channel included in the Raman amplification pumping light is 1.2 μm to 1.3 μm, and the multiplexed signal light near the wavelength of 1.3 μm is Raman-amplified. By this, the transmission distance which is restricted by loss is expanded, or received power increases, and the system margin can be expanded.

For example, when the wavelength of the Raman amplification pumping light is 1.23 μm and the power is 24 dBm, the transmission distance at wavelength 1.33 μm can be 20 km or more longer.

(Third Embodiment)

[0069]   The third embodiment of the optical transmission system according to the present invention will now be described. Fig. 8 is a diagram depicting the configuration of the third embodiment of the optical transmission system according to the present invention. The optical transmission system 3 shown in Fig. 8 comprises N number of (N is an integer 2 or more) direct modulation light sources 11_1 to 11_N (included in the optical transmitter), multiplexer 12, N number of receivers 21_1 to 21_N, demultiplexer 22_1, demultiplexer 22_2, dispersion compensator 23_2, dispersion compensator 23_3, demultiplexer 24_1, demultiplexer 24_2, demultiplexer 24_3, and optical fiber transmission line 30. The following description is based on the configuration where the dispersion compensator 23 is disposed at the signal emitting end side of the optical fiber transmission line 30, as shown in Fig. 8, but in the third embodiment, the dispersion compensator 23 may be disposed at the signal entering end side of the optical fiber transmission line 30, as shown in Fig. 2 as an application example, or the dispersion compensator 23 may be disposed in the middle of the optical fiber transmission line 30. Also in the third embodiment, a configuration which allows hybrid transmission, where the transmission speed is different among signal channels, as shown in Fig. 3, may be used

as another application example.

[0070]   The direct modulation light sources 11_n (n is an arbitrary integer 1 or more N or less) includes a semiconductor laser light source which outputs the signal channels with wavelength of λ_n. The multiplexer 12 multiplexes the signal channels with wavelength λ_n which are outputted from the direct modulation light source 11_n, and sends the multiplexed signal light (including signal channels with wavelengths of λ_1 to λ_N) to the optical fiber transmission line 30. These signal channel wavelengths of λ_1 to λ_N are included in the signal wavelength band from a wavelength of about 1.3 μm to a wavelength of about 1.61 μm, of which the channel spacing is relatively wide. In other words, the optical transmission system 3 is a system which performs CWDM optical transmission.

[0071]   The optical fiber transmission line 30 transmits the signal light, including the signal channels with wavelengths of λ_1 to λ_N, which are outputted from the multiplexer 12, to the demultiplexer 22_1. It is preferable that this optical fiber transmission line 30 is a standard single-mode optical fiber having a zero-dispersion wavelength near the wavelength of 1.3 μm, or a non-zero dispersion shifted optical fiber having a zero-dispersion wavelength within the range of 1.35 μm to 1.5 μm. It is also preferable that the optical fiber transmission line 30, at the wavelength of 1.38 μm, has a transmission loss

smaller than a transmission loss at the wavelength of 1.31 μm.

[0072]   The demultiplexer 22_1 is disposed in the subsequent stage of the optical fiber transmission line 30, and demultiplexes the signal channels with wavelengths of λ_1 to λ_N included in the multiplexed signal light, which propagates through the optical fiber transmission line 30, into the signal channel group in the first wavelength band Λ_1 and the signal channel group in the second wavelength band Λ_2.   The first wavelength band Λ_1 is a wavelength band which includes the zero-dispersion wavelength of the optical fiber transmission line 30, and the second wavelength band Λ_2 is the other wavelength band.   When the optical fiber transmission line 30 is a standard single-mode optical fiber, the second wavelength band Λ_2 is at the longer wavelength side from the first wavelength band Λ_1.   The demultiplexer 22_2 further demultiplexes the signal channel group with wavelengths of λ_{M+1} to λ_N (M is an integer 2 or more (N-1) or less) included in the second wavelength band Λ_2 demultiplexed by the demultiplexer 22_1 into two wavelength bands.

[0073]   The   dispersion   compensator 23_2 dispersion-compensates for the signal channel group with wavelengths of λ_{M+1} to λ_L (L is an integer (M+2) or more (N-1) or less) among the signal channel group in the second wavelength band Λ_2 demultiplexed by the demultiplexer 22_2.

The dispersion compensator 23_3 dispersion-compensates for the signal channel group with wavelengths of λ_{L+1} to λ_N among the signal channel group in the second wavelength band Λ_2 demultiplexed by the demultiplexer 22_3. These dispersion compensators 23_2 and 23_3 have chromatic dispersion with the opposite sign from the chromatic dispersion with the optical fiber transmission line 30 in each wavelength band, and a dispersion compensating optical fiber, for example, is suitable.

[0074]   The demultiplexer 24_1 demultiplexes the signal channel group with wavelengths of λ_1 to λ_M included in the first wavelength band Λ_1, which are demultiplexed by the demultiplexer 22_1, into each signal channel. The demultiplexer 24_2 demultiplexes the signal channels with wavelengths of λ_{M+1} to λ_L among the signal channels in the second wavelength band Λ_2, for which dispersion is compensated by the dispersion compensator 23_2 into each signal channel. The demultiplexer 24_3 demultiplexes the signal channel group with wavelengths of λ_{L+1} to λ_N, for which dispersion is compensated by the dispersion compensator 23_3, into each signal channel. The receiver 21_n receives the signal channel with wavelength λ_n, which is demultiplexed by one of the demultiplexers 24_1 to 24_3, respectively.

[0075]   This optical transmission system 3 operates as follows. The signal channels with wavelength λ_n, which

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are outputted from the direct modulation light source 11_n, are multiplexed by the multiplexer 12, and the multiplexed signal light including the signal channels with wavelengths of λ_1 to λ_N are sent to the optical fiber transmission line 30. The signal channels with wavelengths of λ_1 to λ_N included in the multiplexed signal light, which reached the demultiplexer 22_1 via the optical fiber transmission line 30, are demultiplexed into the signal channel group in the first wavelength band Λ_1 and the signal channel group in the second wavelength band Λ_2 by the demultiplexer 22_1. The signal channel group with the wavelengths of λ_1 to λ_M included in the first wavelength band Λ_1, where the absolute value of chromatic dispersion is small, demultiplexed by the demultiplexer 22_1, are demultiplexed into each signal channel by the demultiplexer 24_1, and received by the receivers 21_1 to 21_M, which each signal channel corresponds to, respectively. The signal channel group with wavelengths of λ_{M+1} to λ_N included in the second wavelength band Λ_2, where the absolute value of chromatic dispersion is large, demultiplexed by the demultiplexer 22_1, on the other hand, are further demultiplexed into two wavelength bands by the demultiplexer 22_2, dispersion is compensated by the dispersion compensators 23_2 and 23_3, and then demultiplexed into each signal channel by the demultiplexers 24_2 and 24_3, then each signal channel is received by the

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corresponding receiver 21_{N+1} to 21_N, respectively.

[0076]   At this time, when the bit rate is B (Gb/s) at a specific wavelength in the second wavelength band Λ_2 where the total chromatic dispersion becomes highest in the optical fiber transmission line 30 and the dispersion compensator 23, the chromatic dispersion value with this specific wavelength is grater than 0 (ps/nm) but $7500/B^2$ (ps/nm) or less.

[0077]   Also in the entire system, the loss at each signal channel in the second wavelength band Λ_2 is set to be lower than the highest loss among losses of the signal channels in the first wavelength band Λ_1. Or the lowest received power among the received powers of the receiver for signal channels in the second wavelength band Λ_2 is set to be higher than the lowest optical power among the optical powers of the signal channels in the first wavelength band Λ_1 of the optical fiber transmission line 30. It is preferable that the total chromatic dispersion in the optical fiber transmission line 30 and the dispersion compensator 23 is set to be grater than 0 (ps/nm) but $7500/B^2$ (ps/nm) or less in each signal channel in the second wavelength band Λ_2 respectively.

[0078]   By setting the chromatic dispersion characteristics and the loss characteristics as above, the optical transmission system 3 allows high quality transmission of multiplexed signal light including a

plurality of signal channels in the signal wavelength band, and becomes a configuration particularly suitable for CWDM optical transmission. Also the dispersion compensators 23_2 and 23_3 are disposed selectively only for the signal channel group in the second wavelength band Λ_2, so system cost decreases. Also the signal channel spacing is wide in CWDM optical transmission, so an inexpensive optical filter can be used for the demultiplexers 22_1 and 22_2. Particularly according to the third embodiment, higher quality signal light transmission is possible because the signal channel group in the second wavelength band Λ_2 is further demultiplexed into two wavelength bands, and a dispersion compensator is disposed for each wavelength band. Also the loss requirement characteristics for the dispersion compensators 23_2 and 23_3 are relaxed, so system design is easy.

[0079]   Figs. 9A and 9B are graphs depicting the chromatic dispersion characteristics and the loss characteristics of the optical transmission system 3 according to the third embodiment. Fig. 9A shows the dependency of accumulated chromatic dispersion on wavelength from the transmitter to the receiver, and Fig. 9B shows the dependency of loss on wavelength from the transmitter to the receiver. When the dispersion compensators 23_2 and 23_3 are not disposed, accumulated chromatic dispersion exceeds the dispersion resistancees

depending on the wavelength (broken line in Fig. 9A).
However in the optical transmission system 3 according
to the third embodiment, the signal channel group included
in the second wavelength band Λ_2 (wavelength range of 1.4

5   µm to 1.61 µm), where the absolute value of chromatic
dispersion is large in the optical fiber transmission line
30, is dispersion-compensated by the dispersion
compensators 23_2 to 23_3, so the accumulated chromatic
dispersion of the entire system becomes the dispersion

10   resistance or less (solid line in Fig. 9A). The length
of the dispersion compensating optical fibers, which are
the dispersion compensators 23_2 and 23_3, is adjusted such
that the accumulated chromatic dispersion becomes the
dispersion resistance or less at the maximum wavelength

15   in each band.

[0080]   Fig. 10 is a diagram plotting the received
power (input power to the receiver) for each channel in
the optical transmission system according to the third
embodiment shown in Fig. 8. The optical fiber transmission

20   line 30 is assumed to be a standard single mode optical
fiber with a length of 80 km. The dispersion compensator
23 is a dispersion compensating optical fiber having a
chromatic dispersion of -100 ps/nm/km, a dispersion slope
of 0 ps/nm^2/km, and a transmission loss of 0.5 dB/km, as

25   characteristics at the wavelength of 1.55 µm. The
insertion loss of the multiplexer 12, demultiplexer 24_1

and demultiplexer 24_2 is 3 dB, respectively. The insertion loss of the demultiplexer 22 is 1 dB. The 16-channel signal light (channel spacing 20 nm) in the wavelength range of 1.31 μm to 1.61 μm are transmitted at a bit rate 2.5 Gb/s.

5   [0081]   It was confirmed that in this system configuration, the lowest received power in the receivers 21_1 to 21_N is -30 dB or more, and BER is $<10^{-13}$ in all the signal channels.

(Fourth Embodiment)

10   [0082]   Now the fourth embodiment of the optical transmission system according to the present invention will be described. Fig. 11 is a diagram depicting the configuration of the fourth embodiment of the optical transmission system according to the present invention. The optical transmission system 4 shown in Fig. 11 further comprises an optical coupler 41 and an pumping light source 42, in addition to the configuration of the optical transmission system 1 according to the first embodiment (Fig. 1). In the following description, the dispersion compensator 23 is disposed at the signal emitting end side of the optical fiber transmission line 30, as shown in Fig. 11, but in the fourth embodiment, the dispersion compensator 23 may be disposed at the signal entering end side of the optical fiber transmission line 30, as shown in Fig. 2, as an application example. Or the dispersion compensator 23 may be disposed in the middle of the optical

fiber transmission line 30. The fourth embodiment may have a configuration which allows hybrid transmission, where the transmission speed is different among the signal channels, as shown in Fig. 3, as another application example.

[0083]   The pumping light source 42 outputs the Raman amplification pumping light, which Raman-amplifies the signal light in the dispersion compensating optical fiber 23, provided as the dispersion compensator. The optical coupler 41 is disposed in the subsequent stage of the dispersion compensating optical fiber 23 and in the previous stage of the demultiplexer 24_2, and supplies the pumping light, which is outputted from the pumping light source 42, to the dispersion compensating optical fiber 23, and also outputs the signal channel group included in the second wavelength band Λ_2 to the demultiplexer 24_2. It is preferable that the Raman amplification pumping light includes a plurality of pumping channels in the wavelength range of 1.2 μm to 1.3 μm, and in this case, the multiplexed signal light in the wavelength range of 1.3 μm to 1.4 μm can be Raman-amplified. At this time, it is preferable that the dispersion compensating optical fiber 23 has a transmission loss at wavelength 1.38 μm, which is smaller than the transmission loss at wavelength 1.31 μm.

[0084]   This optical transmission system 4 operates as follows. The signal channels with wavelength λ_n, which

are outputted from the direct modulation light sources 11_n, are multiplexed by the multiplexer 12, and the multiplexed signal light (including the signal channels with wavelengths of λ_1 to λ_N) are sent to the optical fiber transmission line 30. The signal channels with wavelengths of λ_1 to λ_N included in the multiplexed signal light, which propagates through the optical fiber transmission line 30, are demultiplexed into the signal channel group in the first wavelength band Λ_1 and the signal channel group in the second wavelength band Λ_2 by the demultiplexer 22. The signal channel group with wavelengths of λ_1 to λ_M included in the first wavelength band Λ_1, where the absolute value of chromatic dispersion is small, demultiplexed by the demultiplexer 22, are demultiplexed into each channel and are received by the receivers 21_1 to 21_M which each signal channel corresponds to. The signal channel group with wavelengths of λ_{M+1} to λ_N included in the second wavelength band Λ_2, where the absolute value of chromatic dispersion is large, demultiplexed by the demultiplexer 22, are dispersion-compensated by the dispersion compensating optical fiber 23, and Raman-amplified in the dispersion compensating optical fiber 23, then are demultiplexed to each signal channel and are received by the receivers 21_{M+1} to 21_N which each signal channel corresponds to.

[0085]   At this time, when the bit rate is B (Gb/s)

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at a specific wavelength in the second wavelength band Λ_2, where the chromatic dispersion becomes highest in the optical fiber transmission line 30 and the dispersion compensating optical fiber 23, the chromatic dispersion value at this specific wavelength is set to be grater than 0 (ps/nm) but $7500/B^2$ (ps/nm) or less.

[0086]   Also in the entire system, the loss at each signal channel in the second wavelength band Λ_2 is set to be smaller than the highest loss among losses in the signal channels in the first wavelength band Λ_1. Or the lowest received power among the received powers of the receiver for the signal channels in the second wavelength band Λ_2 is set to be higher than the lowest optical power among the optical powers in the signal channels in the first wavelength band Λ_1 in the optical fiber transmission line 30. It is preferable that the chromatic dispersion in the optical fiber transmission line 30 and the dispersion compensating optical fiber 23 is grater than 0 (ps/nm) but $7500/B^2$ (ps/nm) or less in each one of the signal channels in the second wavelength band Λ_2 respectively.

[0087]   By setting the chromatic dispersion characteristics and the loss characteristics as above, the optical transmission system 4 allows high quality transmission of multiplexed signal light including a plurality of signal channels in the signal wavelength band, and becomes a configuration which is particularly suitable

for CWDM optical transmission. Also the dispersion compensating optical fiber 23 is selectively disposed only for the signal channel group in the second wavelength band Λ_2, so system cost decreases. Also the signal channel

5 spacing is wide in CWDM optical transmission, so an inexpensive optical filter can be used as the demultiplexer 22. In the fourth embodiment, the signal channel group in the second wavelength band Λ_2 is Raman-amplified while propagating through the dispersion compensating optical

10 fiber 23, effective loss of the dispersion compensating optical fiber 23 can be decreased, or effective loss of the dispersion compensating optical fiber 23 can be zero.

[0088]   In particular, 14-channel signal light in the wavelength range of 1.31 μm to 1.61 μm (excluding

15 wavelengths of 1.49 μm and 1.51 μm) are transmitted, where the wavelength of the Raman amplification pumping light is 1.51 μm, and the power of the Raman amplification pumping light is 17 dB. At this time, 4.5 dB gain is obtained at wavelength 1.61 μm, and loss of all the signal channels

20 in the wavelength range of 1.53 μm to 1.61 μm is about 26 dB, therefore a sufficient system margin can be secured.

[0089]   As described above, according to the present invention, high quality transmission of signal light where a plurality of signals channels within the signal

25 wavelength band are multiplexed, becomes possible, and a system particularly suitable for CWDM optical

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transmission can be obtained. Also the dispersion compensation is disposed only for the signal channels in the second wavelength band, and an inexpensive optical component can be used for the demultiplexer, so system cost decreases.

[0090] From the invention thus described, it will be obvious that the embodiments of the invention may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended for inclusion within the scope of the following claims.